Using Social Network Analysis to predict online contributions: The impact of network diversity in cross-cultural collaboration

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ABSTRACT
Although collaborative web-based tools are often used in blended environments such as education, little research has analysed the predictive power of face-to-face social connections on measurable user behaviours in online collaboration, particularly in diverse settings. In this paper, we use Social Network Analysis to compare users' pre-existing social networks with the quantity of their contributions to an online chat-based collaborative activity in a higher education classroom. In addition, we consider whether the amount of diversity present in one's social network leads to more online contributions in an anonymous cross-cultural collaborative setting. Our findings indicate that pre-existing social connections can predict how much users contribute to online education-related collaborative activities with diverse group members, even more so than academic performance. Furthermore, our findings suggest that future Web Science research should consider how the more traditionally 'qualitative' socio-cultural influences affect user participation and use of online collaborative tools.

CCS Concepts
• **Applied computing → Education →Collaborative learning**

Keywords
Social Network Analysis, online collaboration, social networks, group work, cross-cultural collaboration, online contributions

1. INTRODUCTION
In the Web Science community, there is an increased awareness of the impact of social connections on participants' behaviours in online collaboration. For example, [1] found that Twitter replies were motivated more by the relationship between participants than the topic of posts. Similarly, [2] found that new forum users post more often when they have the opportunity to introduce themselves and make social connections with other users. In a study of Facebook users, [3] found that participating in online social communication helped users bridge social capitals.

However, much Web Science research on this topic has focused on social networking sites or leisure use of online collaborative tools (such as forums), and relatively little research on the topic exists in task-oriented settings, such as in education. Additionally, limited research has considered the role of social networks in blended environments (i.e those with both face-to-face and online components), despite the notion that online collaboration has been increasingly incorporated into traditionally face-to-face settings like education. In such contexts, participants have the opportunity to form social relationships within the physical, face-to-face setting (such as a classroom), which may in turn influence how they contribute when using online communication tools with one another. However, to the best of our knowledge, few researchers have analysed the impact of how the physical social environment might impact measurable behaviours in online collaboration, particularly in cross-cultural settings.

Previous research in education has indeed highlighted that cross-cultural collaborative work can be challenging, as many students prefer to work with those from their own cultural background [4], perhaps due to the perception of unequal contributions or 'free riders' (i.e. those who contribute very little to the online activity) [5]. However, more research is needed to better understand why variations in the quantity of online contributions exist, particularly in blended environments. To test this, we used Social Network Analysis in this paper to explore how students' existing social networks within their physical classroom influences how much they contribute to online cross-cultural collaboration.

1.1 Participation in Collaborative Group Work
Previous education research has highlighted that students contribute to online collaboration in different, and often unequal, ways. For example, in a qualitative analysis of student participation in asynchronous online forums, [6] determined that students naturally contribute content to small groups in different ways. Similarly, [7] used k-means clustering of virtual learning environment behaviours to categorise students in virtual math teams, and found that students had varying levels of participation.

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In an analysis of asynchronous forum collaboration, [8] found that a full 80% of posts were made by only 20% of participants.

Unequal participation and 'free riding' are common frustrations felt in online collaborative work in education, as found by [9] in a study of 40 master's level students. In a survey of over 200 students, [5] also found that free-riding was a top complaint. Finally, in a survey of more than 140 students, [10] found that students often listed free-riding as one of the top challenges of cross-cultural collaboration.

One weakness in current research on this topic, however, is that it tends to analyse online participation when participants are in isolation from one another. However, as online components are increasingly incorporated into physical spaces in sectors such as education, it is worth considering the impact of the social environment within which collaboration operates in such circumstances. This consideration is important, as previous research in education has found that students' social connections impact behaviours and perceptions in face-to-face collaborative settings (highlighted in the next section). Thus, Web Science research may need to take into consideration whether social networks also influence user contributions to online collaboration, particularly in blended environments.

1.2 Social Networks and Collaboration

Previous Web Science research has highlighted that social connections affect user participation in online communication [1, 2]. Outside of Web Science, research in the education field has found that social connections influence attitudes towards group collaboration in a face-to-face setting. For example, [11] found that higher education students in classrooms that were more 'cohort-like' (i.e. more socially integrated) felt more positive towards collaborating with one another. Similarly, [12] found in a survey of over 200 students that those with more previous multicultural experiences favoured cross-cultural collaboration more. However, limited research has looked at how social networks impact actual, measurable behaviours when participants who know one another in a face-to-face context collaborate online.

One consideration, thus, is that users with more diverse social networks may enjoy online cross-cultural collaboration more or feel more comfortable working with diverse peers. After all, [13] found by using Social Network Analysis in an education setting that some students act as 'bridge-builders' in diverse classrooms, encouraging interaction between host and international students. Additionally, students with a wider circle of social connections may more naturally contribute more, as strong social networks have also been previously associated with improved academic performance [14].

2. RESEARCH QUESTIONS

In this paper, we consider how participants' position within their social network and their number of diverse social relationships influence the quantity of contributions to an online cross-cultural collaborative activity in a blended higher education setting. Given the gaps highlighted in current literature, we focus on the following research questions:

- How do users' social networks within a face-to-face environment influence the quantity of contributions when they collaborate online?
- To what extent do users' positions within their social network in a face-to-face setting predict their behaviours when they collaborate online?

3. METHODS

3.1 Setting and Participants

This study took place in Masters-level business module at a top 10 UK university. Altogether, there were 118 students from 24 countries enrolled in the module. In week 8, we offered an optional computer lab activity as an opportunity for extra practice with materials that would be covered in an examination, which took place the following week. Altogether, 58 students from 13 countries participated in the lab activity, which was 49% of those registered for the module.

3.2 Procedure

In a computer lab, we used a Harvard Business School case study (available at [15]) and randomly divided participants into small groups to solve a real world problem using only an online chat to communicate. The chat was a built-in function of their university's virtual learning environment, and participants regularly used such online collaboration as part of their wider curriculum. Participants all worked in the same computer lab room on this activity, but were seated strategically around the lab so that they were not seated adjacent to any of their group members. When posting to their chat group, participants' usernames were their student IDs, which were a series of two letters and four numbers (example: AB1234). Thus, participants' identities, including name and culture, were relatively anonymous to their group members unless voluntarily divulged.

Participants were each given short reading materials about the case study and approximately 20 minutes to read, followed by 40 minutes to collaborate in the online chat with group members to determine one best solution to the problem presented. In order to incentivise participation, we divided the case study materials and each participant was given a unique set of information to which their group members did not have access. Participants were then made aware that collaboration would be necessary to understand the full case study.

3.3 Instruments

Social Network Analysis

Social Network Analysis provides a set of tools to analyse connections between individuals in a face-to-face setting, allowing one to discover social and learning relationship patterns [16]. A social network, thus, consists of 'nodes' (i.e. participants) and 'ties' (i.e. relationships between participants). In order to understand users' social networks within the physical space of the classroom, we distributed Social Network Analysis surveys to all students in the module. This survey included a list of all students registered in the module and took place in week four. The survey indicated 'I am friends with…' and participants were asked to mark those with whom they were friends, as demonstrated in previous research [17, 18]. Altogether, we collected surveys from 94 students, which was a response rate of 79.6%. Of the 58 students who participated in the lab activity, 53 participated in the Social Network Analysis survey (91.4%). Surveys were collected from 53 of the 58 lab activity participants (91.4%). However, as relationships in Social Network Analysis are simultaneously indicated and confirmed by multiple individuals within the sample, it is common practice in this methodology to transpose results to

missing respondents [19]. Therefore, all results from all 118 students in the wider classroom are included in our analysis.

Several data were collected from the Social Network Analysis surveys, which were compared with user behaviours in the online chat. First, we were interested in whether participants with more diverse social networks behaved differently online than those with more homogenous networks. Thus, we used an External-Internal (EI) Index, which measures the diversity of an individual's network based on a chosen category. EI Indexes are measured on a -1 to 1 scale, with -1 denoting an exclusive homogenous network and 1 denoting an exclusive heterogeneous network. In our case, we used an EI Index to measure the social relationships participants had either within or outside of their own culture. Because there were many countries from which only one or two participant originated, we opted to group participants' home countries using the GLOBE country cluster system [20], which outlines nine global cultural regions. Thus, the EI Index in our country measures the extent to which participants have social connections from outside their GLOBE country cluster.

We were also interested in whether the quantity of users' social networks affected online behaviours. To measure this, we considered their network density, which is the number of stated social ties divided by the total number of possible ties within the network. Altogether, the Social Network Analysis data in this study can be used as a wider proxy of student attitudes towards working together with classmates from diverse backgrounds.

Discourse in Online Chat

Several data were used to analyse the quantity of user contributions to the chat. We initially looked at the number of posts contributed by each participant. However, some participants had different 'styles' of online communication and opted to write fewer, longer messages to convey their information. Thus, we also considered the summed word count submitted by each participant.

3.4 Data Analysis

We first conducted a graphical representation of participants' social networks by using the software Netdraw, and considered the visual patterns of their social relationships. We then considered whether participants' social connections affected their decision to participate in the online activity. To better understand this, we compared the Social Network Analysis data with a dummy variable that indicated attendance. We then split our data file to analyse only the behaviours of those participants who did attend. To better understand whether social networks affected user behaviours in the online chat, we compared their discourse in online chat (i.e. quantity of contributions) with Social Network Analysis data (i.e. diversity and quantity of social connections) using bivariate and linear regression analysis.

4. RESULTS

We first conducted a graphical analysis of students' social relationships, which is represented in Figure 1. Each node represents one participant, while each arrow indicates a stated relationship, which may or may not be reciprocal. Additionally the colour and shape of the node in Figure 1 represent participants' GLOBE country cluster. Altogether, this graphical analysis indicated that participants' social relationships within the face-to-face setting was often comprised of those from the same country cluster. However, the graph also highlighted that some participants had more diverse social networks than others, as has been demonstrated in previous research [13].

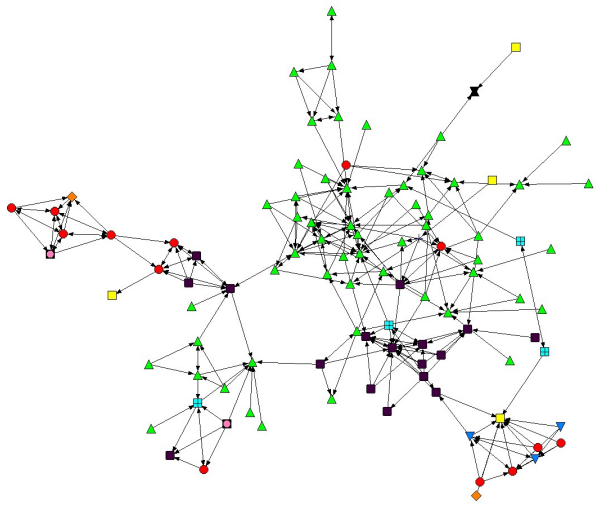

Figure 1: Learning networks as demonstrated by social network survey

In our analysis, we considered whether participants' social networks influenced their initial decision to participate in the optional online activity. After all, participants with fewer diverse social connections might feel less positive about collaborating online with cross-cultural group members, as suggested by [12], and be less inclined to participate. Thus, we conducted a bivariate analysis using Pearson's *R*, comparing a dummy variable that indicated student participation with their EI Index (i.e. network diversity) (R = -.093, p = .315) and social network density (R = .072, p = .441). This analysis indicated no correlation between social networks and decision to participate in the lab activity. We also found no participation biases based on gender or achievement in the module (i.e. examination scores). Thus, no known factors influenced their decision to participate in the activity.

We then split our data set to focus on the behaviours of those who did participate in the activity, and considered whether participants' social relationships affected the quantity of their contributions to the chat. In this case, we again conducted a bivariate analysis using Pearson's *R* to compare the Social Network Analysis data with the number of posts and summed word count submitted, as depicted in Table 1. This analysis indicated that participants with more diverse social networks (i.e. 'learning density') made more contributions online, but there were no correlations between the size of their social network and quantity of contributions. We also considered gender and student achievement (i.e. examination scores), but there were no significant correlations. Thus, diversity of social networks seemed to influence user participation more than the size of their social networks.

Table 1: Bivariate Analysis of Social Network Analysis data and quantity of contributions

Variable	# of Posts	Summed Word Count
Learning EI Index	.410**	.415**
Learning Density	-.003	.142
Gender	-.091	-.063
Examination Score	.151	.103

** p <.01

A regression analysis was conducted with the number of posts as the dependent variable, and EI Index, social network density, gender and examination score as independent variables. This analysis indicated that 18.9% of the variation could be explained by having a diverse social network (i.e. EI Index) ($\beta = .388$, $p = .003$) and a larger social network density ($\beta = .252$, $p = .044$). We then conducted the same regression analysis again, but this time with the summed word count as the dependent variable. In this analysis, 16.0% of the variation between participants could be explained by just one factor: having a diverse social network (i.e., EI Index) ($\beta = .406$, $p = .002$).

5. DISCUSSION

Our findings in this study highlight that in blended environments, the social space within which users participate in online collaboration is a strong predictor of behaviours. This is an important consideration for Web Science researchers, as online collaboration in many fields, such as education or business, also involves a face-to-face element, yet much current research in the field considers users' online behaviours in isolation from the social context in which collaborations may occur. In our study, pre-existing social relationships could predict users' online contributions with anonymous peers, even more so than perhaps more easily 'quantifiable' data about student participants, such as gender or academic achievement. Thus, it is important for future Web Science research to also consider the social and more traditionally 'qualitative' influences within and outside the online environment.

Previous research outside of Web Science has indicated that social networks affect participant attitudes towards cross-cultural collaboration [12, 21]. In this paper, we considered whether social networks can also impact and predict their measurable behaviors in cross-cultural online collaboration (i.e. quantity of contributions). In this regard, we found that those with more diverse social networks contributed more to an online collaborative activity, a notion which builds upon previous findings.

The findings summarised in this paper may also help explain in part the phenomenon of 'free-riders' (i.e. low contributors) highlighted in previous research on online collaboration [6]. In a blended cross-cultural setting, those with less diverse social networks could be predicted to contribute less. Thus, one consideration may be whether participation in online collaborative activities could become more equal with increased opportunity to develop positive social relationships with diverse peers. In this sense, increased exposure to diversity could help alleviate the frustrations participants have expressed in previous studies about unequal participation in online collaboration [5, 10].

However, it also worth considering whether developing a diverse social network is simply a result of being highly active within the classroom in the first place (i.e. correlation, but not causation). After all, previous research has indicated that 'bridge builders' between culturally diverse groups tend to also demonstrate good leadership skills [13]. More research, thus, will be necessary to unpack and understand why diverse social connections predict participation levels, and whether the influence is direct or indirect. For example, one consideration may be that students with more homogenous social networks also have lower English language proficiency, and are, thus, less able to engage with the activity materials and participate in in-depth discussion. However, it is important to note that international students in the UK must demonstrate English language skills proficient enough for university study in order to receive a student visa.

Yet overall, it is noteworthy that our analysis found that social connections are a better predictor for participation in education-related online collaboration with diverse peers than academic performance. In this study, those who were more active online were those with social agency and the ability to network with a diverse group of peers. More interestingly, this difference in participation occurred even when the cultural background of those with whom they were collaborating was unknown. This notion – that a diverse social network can predict increased participation in online collaboration with anonymous peers – certainly has implications for Web Science research.

6. CONCLUSIONS

In this paper, we have analysed the predictive power of pre-existing social connections in a physical, face-to-face setting with the quantity of user contributions to an online cross-cultural collaboration. In doing so, we have highlighted that the social environment is an important consideration for future Web Science research, particularly in blended settings which also incorporate a face-to-face element. However, we also recognise several limitations in this paper. First, this study was conducted with a relatively small sample size in just one context; further research and replication will be necessary to confirm our findings. We also recognise that our social network surveys only captured participants' social networks within their module, and more variation may be present in their social networks beyond the module.

Despite these limitations, this preliminary research does set a foundation for future research on this topic. One suggestion for future research is to include in the analysis more fine-grained data about participants, such as tested English language ability or length of stay in the host nation. Similarly, future research might explore imposed network effects of small group assignments, perhaps in a randomized control trial setting. In summary, this study highlights that variations in user participation in online collaboration can perhaps be predicted by the pre-existing diversity of their social connections in a face-to-face environment, a notion that has important consequences for future Web Science research.

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